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Effects of dietary energy on growth, carcass characteristics, meat quality, and blood biochemical parameters of BAU Black and White ducks

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ABSTRACT

Duck is one of the important poultry genetic resources in Bangladesh, primarily used for egg and meat production. This study aimed to determine the optimal dietary energy levels for improving growth performance, carcass characteristics, meat quality, and blood biochemical parameters in BAU Black and White crossbred ducks. Four dietary treatments (T_1 to T_4) were formulated with energy levels ranging from 2700 to 3000 kcal/kg in 100 kcal/kg increments. A total of 160-day-old ducklings were randomly distributed in four different pens, having 40 birds per treatment, and reared up to 8th week of age. Live weight (BWT) was measured weekly, and at the end of the 8th week, birds were slaughtered to investigate carcass characteristics and meat quality parameters. Growth performance differed significantly ($p<0.01$) from weeks 1 to 8, with T_3 (2900 kcal/kg) achieving the highest BWT, average daily gain, and better feed conversion ratio among the treatments. Carcass characteristics showed significant differences ($p>0.05$) only for BWT, back-half weight, and breast muscle weight ($p<0.05$). However, dietary energy levels had no significant ($p>0.05$) effects on meat quality parameters such as cooking loss, drip loss, and water holding capacity. Only low-density lipoprotein showed a significant difference ($p<0.05$) among the treatments out of 11 blood biochemical markers investigated. Taken together, this study optimized dietary energy level at 2900 kcal/kg feed, which may be utilized in rations for better growth performance without compromising the carcass characteristics or meat quality of BAU Black and White ducks.

INTRODUCTION

Duck (*Anas platyrhynchos*) is an important poultry species in many developing countries, including Bangladesh, where they are prized for their excellent foraging abilities, long productive lifespan, and better resilience to diseases [1]. In Bangladesh, ducks are the second most prevalent poultry species after chickens and are primarily raised by smallholders under semi-intensive management practices for both egg and meat production. The total duck population of Bangladesh is about 68.26 million [2]. All Bangladeshi communities, regardless of caste, religion, or creed, like duck meat. Nonetheless, the native duck, along with a few egg-type duck breeds, like Indian Runner, Jinding, and Khaki Campbell, provides the majority of the duck meat needed. The world-renowned Pekin duck, on the other hand, has a limited capacity for production due to its inability to adapt to scavenging or semi-scavenging environments. Therefore, creating crossbred or improved duck genotypes using more productive exotic and better-adapted local duck breeds may be an alternate way to overcome the existing limitations. Crossbreeding or upgrading has been practiced in many duck populations worldwide in order to harness heterosis or hybrid vigor in the resulting crossbreds [3-5]. The BAU Black and White duck, a cross between the Pekin and Nageswari breeds, has been developed to enhance both egg and meat yields. The Nageswari is an indigenous duck breed of Bangladesh, well known for its moderate egg production (approximately 200 eggs annually) and well-suited to Bangladesh's farming practices and environmental conditions [6,7], while Pekin ducks are globally recognized for their meat production potential [8]. Prior studies have explored the morphology, growth performance, and carcass traits of BAU Black and White crossbred ducks [3,5]. However, no research has yet been conducted to determine the optimal dietary energy levels for this crossbred.

Dietary energy is a critical factor in poultry production, directly influencing growth performance, feed efficiency, and overall production costs. Determining the optimal energy level is essential for reducing overall feed cost per unit. Adequate energy levels improve feed conversion efficiency, which is a crucial aspect for maximizing production output, yet excessive energy can lead to undesirable abdominal fat accumulation, potentially resulting in economic losses for producers [9,10]. To fully unlock the genetic potential of poultry breeds for specific production goals, it is essential to gain a deeper understanding of their nutritional requirements [11]. Despite its importance, the research on the optimal energy requirements for ducks has been relatively scarce, and is absent, particularly for the newly developed crossbred ducks using a limited range of energy levels. Recent findings suggest that the energy requirements of growing Pekin ducks are higher than previously anticipated [9,10,12], which mirrors the significance of nutrient requirement optimization for a specific genotype. Therefore, this study aims to investigate the effects of varying dietary energy levels on growth performance, carcass characteristics, meat quality, and blood biochemical parameters of BAU Black and White ducks, with the goal of determining the optimal energy level for this breed's development.

MATERIALS AND METHODS

Ethical approval

This study was conducted following guidelines set by the Ethical Standard of Research Committee, Bangladesh Agricultural University Research System (Approval No.: BAURES/ESRC/92/AH/2025).

Experimental design

Fertile eggs were collected from the 5th generation flock of BAU Black and White crossbred ducks. Eggs were screened based on shape, size, egg weight, and any small cracks in the shell. After hatching, a total of 160-day-old ducklings were randomly allocated into 4 different groups with an equal number for this experiment. During the first week, the ducklings were fed a commercial starter ration (Nourish Feeds Ltd.). From 2^{nd} to 8^{th} week of age, the experimental birds were given a dose-response regimen with four dietary energy levels (2700, 2800, 2900, and 3000 Kcal/Kg), which corresponded to four treatments (T_1, T_2, T_3, and T_4) with similar crude protein (18.5%) contents. The composition of the experimental ration is given in Table 1.

Table 1. Composition of experimental rations.

Feed ingredient	Dietary energy level (kcal/kg)			
	2700	2800	2900	3000
Maize (kg)	41.00	46.00	58.00	57.00
Rice polish (kg)	24.70	25.00	12.50	10.00
Wheat bran (kg)	4.80	-	-	-
Soyabean meal (kg)	26.20	22.90	22.10	24.50
Soyabean oil (liter)	-	-	0.50	2.40
Fish meal (kg)	-	3.00	4.57	3.50
Limestone (kg)	1.80	2.00	1.40	1.48
Di-calcium phosphate (kg)	0.88	0.55	0.38	0.55
Vitamin-mineral premix (kg)	0.25	0.25	0.25	0.25
Salt (kg)	0.25	0.25	0.25	0.25
DL-methionine (kg)	0.20	0.20	0.20	0.20
Lysine (kg)	0.20	0.20	0.20	0.20
Calculated composition				
Metabolizable energy (kcal/kg)	2700	2806	2908	3001
Crude protein (%)	19.01	19.06	19.02	19.04
Calcium (%)	1.01	1.18	1.00	1.00
Available phosphorus (%)	0.40	0.41	0.40	0.40
Lysine (%)	1.09	1.10	1.08	1.09
Methionine (%)	0.39	0.43	0.43	0.42
Methionine + Cysteine (%)	0.71	0.70	0.67	0.67
Analyzed composition				
Crude protein (%)	18.85	18.87	18.75	18.99

Management practices

Ducklings were reared on a concrete floor where rice husk was used as bedding material. Brooding was provided up to 3rd week of age. Feed requirements of the birds were balanced based on the dual-purpose duck. Handmade wet mash feed was provided twice daily in the morning and afternoon. At the same time, clean drinking water was supplied *ad libitum* by plastic drinkers. Ducklings were vaccinated against duck plague, avian influenza, and duck cholera. Birds were allowed to move in the run for three to four hours every day.

Growth performance

Body weight and feed intake data were recorded every week early in the morning before being supplied with feed and water, continuing until the 8th week of age. Any leftover feed was measured the next morning. Average daily gain (ADG) and Feed conversion ratio (FCR) were calculated using body weight and feed intake data. In addition, the mortality of birds was recorded when death occurred.

Blood sampling and biochemical analysis

At the end of 8th week, four ducks (2 males and 2 females) were randomly selected from each treatment, and in total, 16 blood samples (2~3 ml) were collected from the wing vein using a 5 ml venoject tube for blood biochemical test. Samples were centrifuged (Tomy Digital Biology Co. Ltd., Tokyo, Japan) at 3000 rpm for 10 min in order to separate serum from the whole blood, and the blood serum was stored at -20ºC until further use. The investigated blood biochemical parameters were serum glutamic-pyruvic transaminase (SGPT), total protein (TP), albumin (ALB), globulin (GLU), cholesterol (CL), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), phosphorus (P), calcium (Ca), creatinine (Cre), triacylglycerol

(TAG) levels using Agape mispa cxl Pro (Agappe Diagnostics Ltd., Model 4715MS, Kerala, India) machine following the provided protocol of the analyzer.

Carcass characteristics and meat quality parameters

A total of 16 ducks were slaughtered by the halal method, bled out completely, and soaked in warm water for defeathering. Finally, the eviscerated carcasses were hung for a while and wiped with kitchen tissue to remove water from the body, and were measured by a digital weighing balance. The carcass traits such as body weight (BWT), warm carcass weight (WCWT), dressing percentage (DP), back-half weight (BHWT**),** breast meat weight (BMWT), thigh with drumstick weight (TDWT), wing weight (WWT), neck weight (NWT), giblet weight (GWT), head weight (HWT), and abdominal fat weight (AFWT) were investigated according to the method outlined by Ahmad *et al.* [3]. Breast and thigh muscles from both sides of the carcass were skinned and deboned to investigate the following meat quality parameters as cooking loss (CL), drip loss (DL), and water holding capacity (WHC). To determine cooking loss, 10g of each meat sample was wrapped in heat-stable foil paper and kept in a water bath (JS Research Inc., Gongju, South Korea) at 80°C for 30 minutes, dried, and weighed. Cooking loss was calculated as the percentage of the loss of the cooked sample [13].

$$\text{Cooking loss (\%)} = \frac{W1 - W2}{W1} \times 100$$

Where W_1 and W_2 were the meat weights before and after cooking, respectively.

Drip loss was calculated by placing 15g meat samples in inflated polythene bags, placing them in an airtight box by hanging them on a string, and storing them for 24 hours at 4ºC. After that, samples were dried and weighed, and drip loss was calculated as the weight loss percentage [14].

$$\text{Drip loss (\%)} = \frac{\text{Sample initial weight} - \text{sample weight after 24 hours}}{\text{Sample initial weight}} \times 100$$

Water Holding capacity was determined by centrifugation assay, and 1g sample was cut into small cubes and placed in a microcentrifuge tube to be centrifuged (Dynamica Scientific Ltd., Newport Pagnell, UK) at 1000 RCF at 4ºC for 10 minutes. The WHC was calculated by the following formula:

$$\text{WHC (\%)} = 100 - \left(\frac{\text{Sample weight before centrifugation} - \text{Sample weight after centrifugation}}{\text{Sample weight before centrifugation}} \times 100\right)$$

The dressing percentage was calculated by following the formula:

$$\text{Dressing Percentage (DP) \%} = \frac{\text{Whole carcass weight}}{\text{Live weight}} \times 100$$

Statistical analysis

Data from the experimental record book was compiled into an Excel sheet using Microsoft Office 2019. Extreme values were removed, and descriptive statistics (mean, standard error, frequency, and percentage distribution) were calculated. ANOVA with a random design was performed using the Agricolae package in R with a completely randomized design (CRD) [15], and the Pastecs package tested for significant variation in means [16]. Dietary energy levels were treated as fixed effects, and their impact was computed using the model below:

$$Y_{ij} = \mu + T_i + e_{ij}$$

Where, Y_{ij} = the dependent variable (traits), μ = the overall mean, T_i = the fixed effect of ith treatments (T_1, T_2, T_3 and T_4), and e_{ij} = the residual error

RESULTS

Effect of dietary energy levels on growth performance

Table 2 represents the effects of dietary energy levels on the growth performance of BAU Black and White crossbred ducks up to 8^{th} week of age. Weekly growth performance had a highly significant difference among the 4 dietary treatment groups, although there were some disparities observed in their growth performances, and did not increase linearly with age (Table 2). A similar trend was noticed in the resultant ADG and FCR of four dietary treatments (Table 3). Both parameters differed significantly across the treatments from 1^{st} week to 8^{th} week of age. However, ducks fed a 2900 kcal/kg (T_3) ration had the highest ($p<0.01$) BWT, differing insignificantly with the treatments T_4 (3000 kcal/kg) and T_2 (2800 kcal/kg) while T_1 (2700 kcal/kg) treatment showed the lowest ($p<0.01$) BWT at 8^{th} week of age (marketing age). The FCR varied from 1.03 to 1.13 at the 1^{st} week, and it ranged between 3.69 and 4.38 at 8^{th} week of age (Table 3).

Table 2. Effect of dietary energy levels on growth performance of BAU Black and White crossbred duck up to 8^{th} week of age.

Age in Week	Live weight (g)				P-value
	T_1 (n=40)[1]	T_2 (n=40)	T_3 (n=40)	T_4 (n=40)	
DOC	40.03 ± 0.66	41.33 ± 0.56	41.00 ± 0.55	41.35 ± 0.55	0.339
1^{st}	$120.55^{b}\pm2.07$	$126.23^{ab}\pm2.09$	$130.55^{a}\pm2.41$	$127.15^{ab}\pm2.01$	0.012
2^{nd}	$273.90^{c}\pm4.70$	$292.58^{ab}\pm4.81$	$299.13^{a}\pm4.92$	$281.03^{bc}\pm4.30$	0.001
3^{rd}	$457.75^{b}\pm8.00$	$474.03^{ab}\pm6.70$	$493.68^{a}\pm7.33$	$487.53^{a}\pm9.39$	0.008
4^{th}	$701.10^{b}\pm12.90$	$707.41^{ab}\pm11.86$	$750.18^{a}\pm10.77$	$730.95^{ab}\pm14.28$	0.024
5^{th}	$897.31^{c}\pm16.98$	$911.77^{bc}\pm14.99$	$967.18^{ab}\pm13.52$	$987.54^{a}\pm19.29$	0.000
6^{th}	$1108.03^{b}\pm23.01$	$1132.49^{b}\pm18.00$	$1214.20^{a}\pm20.26$	$1230.85^{a}\pm25.66$	0.000
7^{th}	$1285.40^{b}\pm25.22$	$1318.95^{b}\pm20.52$	$1417.65^{a}\pm21.50$	$1414.90^{a}\pm29.48$	0.000
8^{th}	$1492.90^{b}\pm29.04$	$1540.58^{ab}\pm20.96$	$1634.18^{a}\pm24.83$	$1606.72^{a}\pm33.50$	0.001

T_1, T_2, T_3, and T_4 represent different energy levels in the duck rations as 2700, 2800, 2900, and 3000 kcal/kg, respectively. Means with different superscripts in the same row differ significantly in the energy content level ($P<0.05$). DOC, Day-old chicks.

Table 3. Effect of dietary energy levels on the FCR and ADG (g) of BAU Black and White crossbred duck up to the 8^{th} week of age.

Week	Traits	Dietary energy level				P value
		T_1(n=40)[1]	T_2(n=40)	T_3(n=40)	T_4(n=40)	
1^{st}	FCR	$1.13^{a}\pm0.01$	$1.10^{ab}\pm0.01$	$1.03^{c}\pm0.01$	$1.07^{bc}\pm0.01$	0.000
	ADG	$11.99^{c}\pm0.15$	$12.32^{bc}\pm0.14$	$13.09^{a}\pm0.12$	$12.66^{ab}\pm0.14$	0.000
2^{nd}	FCR	$2.05^{a}\pm0.03$	$1.93^{b}\pm0.02$	$1.88^{b}\pm0.02$	$2.01^{a}\pm0.02$	0.000
	ADG	$22.12^{b}\pm0.29$	$23.45^{a}\pm0.24$	$24.03^{a}\pm0.26$	$22.51^{b}\pm0.22$	0.000
3^{rd}	FCR	$2.47^{a}\pm0.05$	$2.43^{ab}\pm0.05$	$2.30^{b}\pm0.04$	$2.10^{c}\pm0.04$	0.000
	ADG	$25.86^{c}\pm0.49$	$26.16^{bc}\pm0.43$	$27.67^{b}\pm0.45$	$30.29^{a}\pm0.50$	0.000
4^{th}	FCR	$2.33^{ab}\pm0.05$	$2.44^{a}\pm0.05$	$2.23^{b}\pm0.03$	$2.38^{ab}\pm0.06$	0.020
	ADG	$35.54^{ab}\pm0.51$	$34.17^{b}\pm0.43$	$36.64^{a}\pm0.53$	$35.85^{ab}\pm0.59$	0.010
5^{th}	FCR	$3.38^{a}\pm0.10$	$3.12^{ab}\pm0.06$	$2.93^{b}\pm0.04$	$2.60^{c}\pm0.10$	0.000
	ADG	$29.86^{b}\pm0.76$	$29.41^{b}\pm0.45$	$31.00^{b}\pm0.47$	$37.06^{a}\pm0.62$	0.000
6^{th}	FCR	$3.23^{a}\pm0.08$	$3.17^{a}\pm0.05$	$2.83^{b}\pm0.08$	$2.97^{ab}\pm0.11$	0.003
	ADG	$31.22^{b}\pm0.79$	$31.53^{b}\pm0.52$	$36.00^{a}\pm0.79$	$34.86^{a}\pm0.84$	0.000
7^{th}	FCR	$4.27^{a}\pm0.09$	$4.08^{ab}\pm0.05$	$3.74^{c}\pm0.05$	$3.95^{bc}\pm0.09$	0.000
	ADG	$25.34^{b}\pm0.51$	$26.60^{b}\pm0.36$	$28.91^{a}\pm0.39$	$26.29^{b}\pm0.72$	0.000
8^{th}	FCR	$3.97^{b}\pm0.09$	$3.69^{b}\pm0.05$	$3.84^{b}\pm0.08$	$4.38^{a}\pm0.14$	0.000
	ADG	$29.63^{a}\pm0.58$	$31.66^{a}\pm0.48$	$30.93^{a}\pm0.59$	$27.45^{b}\pm0.67$	0.000

T_1, T_2, T_3, and T_4 represent different energy levels in the duck rations as 2700, 2800, 2900, and 3000 kcal/kg, respectively. Means with different superscripts in the same row differ significantly in the energy content level ($P<0.05$). Feed conversion ratio (FCR) and average daily gain (ADG).

Effect of dietary energy levels on carcass characteristics

The effect of dietary energy levels on different carcass characteristics is shown in Table 4. Randomly selected slaughtered ducks showed significant differences in body weight (BWT), back half weight (BHWT), and breast muscle weight (BMWT) across four different dietary energy levels ($p<0.05$). Ducks fed with a 2900 kcal/kg ration (T_3) had significantly higher BWT and BHWT ($p<0.05$) compared to the treatments T_1 and T_2, while showing no significant difference from T_4. Further, the highest BMWT (277.75±12.53g) was found in T_3 group, which differed insignificantly with T_2 (250.50±11.74g) and T_4 (261.50±7.85g) groups, and the lowest weight was observed in T_1 treatment (230.50±11.00g). However, the remaining nine carcass traits did not differ significantly ($p>0.05$) among the treatment groups.

Table 4. Effect of dietary energy contents on carcass characteristics of BAU Black and White ducks at the 8th week of age.

Traits	Carcass characteristics				P-value
	T_1 (n=4)	T_2 (n=4)	T_3 (n=4)	T_4 (n=4)	
BWT (g)	1790.50^{b}±32.70	1808.50^{b}±34.01	1925.50^{a}±47.45	1892.75^{a}±14.18	0.040
WCWT (g)	1272.25±39.56	1280.50±35.31	1357.00±47.38	1363.00±29.52	0.245
DP (%)	71.03±1.30	70.78±0.76	70.43±1.05	71.99±1.02	0.754
BHWT (g)	434.50^{b}±9.61	435.75^{b}±15.81	482.25^{a}±13.85	477.75^{a}±6.52	0.022
BMWT (g)	230.50^{b}±11.00	250.50^{ab}±11.74	277.75^{a}±12.53	261.50^{ab}±7.85	0.049
TDWT (g)	277.25±12.63	309.25±37.41	291.00±12.66	297.50±5.45	0.751
WWT (g)	210.25±9.01	196.25±5.36	184.50±11.92	197.25±6.24	0.259
NWT (g)	212.50±6.55	208.00±10.28	216.25±5.88	209.00±13.15	0.923
GWT (g)	117.00±4.74	112.75±6.06	118.00±4.78	105.50±4.50	0.331
HWT (g)	59.75±0.85	64.75±4.31	64.50±2.66	63.50±1.71	0.553
AFWT (g)	7.00±3.34	8.00±0.00	12.67±2.03	13.50±8.50	0.658

BWT, Body weight; WCWT, Warm carcass weight; DP, Dressing percentage; BHWT, Back-half weight; BMWT, Breast muscle weight; TDWT, Thigh with drumstick weight; WWT, Wing weight; NWT, Neck weight; GWT, Giblet weight; HWT, Head weight; SWT, Skin weight and AFWT, abdominal fat weight. T_1, T_2, T_3, and T_4 represent different energy levels in the duck rations as 2700, 2800, 2900, and 3000 kcal/kg, respectively. Means with different superscripts in the same row differ significantly in the energy content level ($P<0.05$)

Effect of dietary energy levels on meat quality parameters

There were no significant differences ($p>0.05$) observed in cooking loss, drip loss, or water-holding capacity (WHC) for both breast and thigh muscle (Table 5). However, cooking loss and drip loss were higher in BM compared to TM. In contrast, water retention capacity was found to be better in TM.

Table 5. Effect of dietary energy levels on meat quality parameters of BAU Black and White ducks at 8th week of age.

Treatment	Meat quality paramter					
	Breast muscle (BM)			Thigh muscle (TM)		
	CL%	DL%	WHC%	CL%	DL%	WHC%
T_1 (n = 4)	36.11±1.44	5.61±1.14	93.80±0.58	33.93±0.58	2.44±0.63	95.90±0.75
T_2 (n = 4)	36.53±1.21	5.02±1.08	94.62±0.76	32.78±0.71	1.64±0.34	97.00±0.44
T_3 (n = 4)	34.65±0.41	4.29±0.31	94.92±0.95	33.84±1.12	0.90±0.24	97.77±0.46
T_4 (n = 4)	36.13±0.50	4.63±0.61	95.16±0.64	34.54±1.30	1.46±0.19	96.71±0.46
P - value	0.573	0.728	0.611	0.715	0.095	0.163

T_1, T_2, T_3, and T_4 represent different energy levels in the duck rations as 2700, 2800, 2900, and 3000 kcal/kg, respectively. CL, Cooking loss; DL, Drip loss; WHC, Water holding capacity. Means with different superscripts in the same row differ significantly in the energy content level ($p<0.05$)

Effect of dietary energy levels on blood biochemical parameters

Table 6 shows the effects of dietary energy levels on the blood biochemical parameters of BAU Black and White ducks. The experiment found significant ($p<0.05$) increases in LDL levels across different dietary energy levels (Table 6). However, there were no statistical differences in SGPT, TP, ALB, GLU, CL, HDL, P, Ca, Cre, and TAG among the different dietary energy levels.

Table 6. Effect of dietary energy levels on blood biochemical parameters of BAU Black and White ducks.

Parameter	Dietary energy level				P-value
	T_1(n=4)	T_2(n=4)	T_3(n=4)	T_4(n=4)	
SGPT (U/L)	30.28±2.36	33.05±1.34	24.18±2.53	25.73±4.00	0.096
TP (g/dL)	3.50±0.07	3.88±0.10	3.49±0.17	3.46±0.17	0.138
ALB (g/dL)	1.68±0.02	1.79±0.06	1.62±0.03	1.63±0.05	0.085
GLU (mmol/L)	9.40±0.38	10.38±0.75	11.13±0.33	9.98±0.53	0.179
CL (mg/dL)	141.75±7.24	164.28±8.44	163.07±8.92	166.77±8.62	0.163
HDL (mg/dL)	195.67±19.34	204.58±12.12	233.80±20.75	211.68±10.63	0.422
LDL (mg/dL)	37.83^{b}±4.03	49.87^{ab}±6.81	52.65^{ab}±3.07	58.33^{a}±4.19	0.035
P (mg/dL)	3.32±0.44	3.45±0.85	3.15±0.59	2.96±0.23	0.939
Ca (mg/dL)	12.25±0.35	12.50±0.86	11.50±0.64	12.58±0.66	0.647
Cre (mg/dL)	0.26±0.12	0.17±0.01	0.16±0.02	0.17±0.02	0.542
TAG (mg/dL)	91.35±8.42	73.78±16.26	78.15±9.45	75.25±2.75	0.707

Serum glutamic-pyruvic transaminase (SGPT), Total Protein (TP), Albumin (ALU), Globulin (GLU), Cholesterol (CL), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), Phosphorus(P), Calcium (Ca), creatinine (Cre), Triacylglycerol (TAG). T_1, T_2, T_3, and T_4 represent different energy levels in the duck rations as 2700, 2800, 2900, and 3000 kcal/kg, respectively. Means with different superscripts in the same row differ significantly in the energy content level ($P<0.05$).

DISCUSSION

The dietary energy level is an important issue in the animal production industry since optimization of nutrient requirements is a major step to ensure maximizing productivity with minimum production cost. High-energy diets improved BWT, ADG, and FCR [17-19]. The present study found lower BWT compared to White Pekin ducks [10] and Muscovy ducks [20] at similar and different energy levels, respectively. Shin *et al.* [21] and Kim *et al.* [22] studied under heat stress conditions between 2900 and 3200 kcal/kg with 100 kcal/kg gaps and low ambient temperatures between 2950 and 3150 kcal/kg dietary energy levels with 50 kcal/kg intervals up to 6th week of age. They discovered that the average BWT of Cherry Valley and Pekin ducks was greater than ours, which might be due to differences in genotype and environment. According to the reports of Makram *et al.* [4] and Ebnat *et al.* [5], dietary differences caused the average BWT of Pekin × Nageswari (1474.59 ± 13.22 g) and Pekin × Sudani (2548.52 ± 85.86 g) crossbreds at 8th week of age to be comparatively lower and higher than the current study, respectively. It is important to note that, unlike other livestock and poultry species, crossbreeding in ducks is relatively less; therefore, the current results may only be roughly compared with those of previous studies. Growth variations may result from genotype (selected and unselected), nutrition, rearing systems, and feeding frequency, etc. Our findings were supported by Fan *et al.* [9] and Hong *et al.* [10], who noted that the increase in feed conversion efficiency (FCR) was caused by rising body weight and reduced feed consumption brought on by providing high-energy diets in growing Pekin ducks. According to Wen *et al.* [19], dietary energy regulates feed intake and thereby impacts FCR. This suggested that, in order to attain energy balance and appropriate growth, birds on the low-energy diet consumed more feed than those on the high-energy diet.

In the duck meat industry, carcass quality is significant since it determines yield and the quality of the meat for subsequent processing. Hong *et al.* [10] found no significant difference in breast meat yield when dietary energy was increased. High-energy diets have been linked to excess carcass or belly fat deposition in growing ducks [9,10] and in broilers [18], and this agrees with the current study. Studies confirmed that dietary energy did not impact meat yield but increased abdominal fat [10,12,23] and supported the present findings. Carcass characteristics are influenced by the type of bird, size, genetics, environment, stress conditions before slaughtering, and feed [24].

Research on how dietary energy affects duck meat quality as measured by CL, DL, and WHC is crucial. According to Ali *et al.* [25], the CL values of the breast meat of Cherry Valley ducks were 34.48%, whereas those of Pekin ducks after 0.25 hours were 31.26%. However, the CL of duck meat varied for different deboning times [26] and is comparable to our results. Similar to our investigation, Muhlisin *et al.* [27] reported no statistically significant difference in CL between leg and breast meat in both Korean native ducks and imported commercial ducks, which is consistent with the present findings. High drip loss lowers product output for poultry processors and inhibits the ability to produce further processed chicken products [28]. Our research indicates that, over a range of dietary energy levels, there was no statistically significant difference in DL between breast and thigh meat. According to Huda *et al.* [29], a low WHC may also cause more water to be released throughout the processing, storage, and distribution of raw beef, which could lead to weight losses in the finished product as well as financial losses. There is no discernible difference in WHC between thigh and breast meat in terms of dietary energy. Nevertheless, information on WHC, CL, and DL values for various dietary energy levels in ducks is scarce, which limits to compare the present dataset with earlier findings.

Blood biochemical indices can show variations in an animal's growth, development, and metabolism [30]. In contrast to our findings, Shin *et al.* [21] found that in Cherry Valley ducks exposed to heat stress, rising dietary energy levels caused changes in TAG, TC, LDL, HDL, and glucose. These results indicate that environmental stress plays an important role in animals' physiology and blood parameters. Wang *et al.* [31] reported that changes in dietary ME levels would surely result in changes in food metabolism, which might be reflected in changes in blood biochemistry. Oler and Glowinska [32] and Graugnard *et al.* [33] also noted that dietary energy levels impacted metabolism, which in turn impacted serum GLU concentration. Basmacioğlu and Ergül [34] stated that blood LDL levels should be less than 130 mg/dL, and Fita [35] reported that poultry blood LDL levels vary from 31.6 to 62.07 mg/dL, which is comparable to the range of our results. The results of our study are supported by the TAG healthy category values, which are lower than 90 mg/dl for children and teens and less than 150 mg/dl for adults [36]. Similar to our findings, Rabie *et al.* [37] and Kim *et al.* [22] found that dietary energy had no effect on blood biochemical markers in Pekin ducks and Mamourah Cockerels. Currently, there is little published literature available on blood biochemical data in purebred or crossbred ducks at varying dietary energy levels. Taken together, this study manifested the growth performances and carcass characteristics of BAU Black and white crossbred ducks at variant dietary energy levels up to 8th week of age and thus optimized energy levels for increasing growth performance. However, care has to be taken for utilizing the optimized energy level on a broader scale at the field level, as the sample size of this experiment is relatively small. Furthermore, the study was carried out under a single set of management and environmental settings; therefore, changes in the climate, rearing method, or feed ingredients may have an impact on the findings.

CONCLUSIONS

The optimal dietary energy level for BAU Black and White ducks, according to this study, is 2900 kcal/kg, which enhances growth performance without affecting meat quality or most of the carcass traits, with the exception of BWT, BHWT, and BMWT. In addition, blood biochemical parameters did not vary significantly among different energy levels, except for the trait LDL. Considering all, this study provides important information on dietary energy content in order to attain optimum growth performances and better carcass yield and quality.

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AUTHOR CONTRIBUTIONS

KCB and MSAB conceptualized and designed the study; KCB drafted the manuscript; KCB, MA, PS, and MAHP collected phenotypic performance data, sampling, wet lab experimentation, and data analysis. MMH and MSAB are involved in reviewing the manuscript.

CONFLICTS OF INTEREST

There is no conflict of interest among the authors.

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